

# The growth with energy of exclusive $J/\Psi$ and $\Upsilon$ photo-production cross-sections and BFKL evolution

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**Abstract.** We investigate whether NLO BFKL evolution is capable to describe the energy dependence of the exclusive photo-production cross-section of vector mesons  $J/\Psi$  and  $\Upsilon$  on protons. Our description is based on available NLO BFKL fits of the proton impact factor in inclusive DIS, which allow us to construct the necessary scattering amplitude at zero momentum transfer  $t = 0$ . Assuming an exponential drop-off with  $t$ , this result allows us to calculate the exclusive photoproduction cross-section. Comparing our results with both HERA data (measured by H1 and ZEUS collaborations in  $ep$  collision) and LHC data (measured by ALICE, CMS and LHCb collaborations in ultra-peripheral  $pp$  and  $pPb$  collision) we find that our framework provides a very good description of the energy dependence of the  $J/\Psi$  and  $\Upsilon$  photoproduction cross-section, providing therefore further evidence for BFKL evolution at the LHC. The available fits of the proton impact factor require on the other hand an adjustment in the overall normalization.

## INTRODUCTION

Ultra-peripheral collisions at the LHC provide currently the most energetic photon-proton collisions measured so far. In particular such reactions allow to probe the gluon distribution in the proton down to ultra-small values of Bjorken  $x$ , increasing the range probed by the HERA experiments roughly by an order of magnitude. A particular interesting class of events are exclusive photo-production of vector mesons  $J/\Psi$  and  $\Upsilon$  where the mass of the charm ( $J/\Psi$ ) and bottom ( $\Upsilon$ ) quarks provide a hard mass scale, allowing therefore for an analysis within perturbative Quantum Chromodynamics. If current LHC data [1, 2, 3, 4] are complement with HERA data [5, 6, 7, 8, 9, 10, 11] measured at lower values of the collision energy  $W$  of the effective photon-proton collisions, these measurements allow to probe Balitsky-Fadin-Kuraev-Lipatov (BFKL) evolution [12, 13] over two orders of magnitude in  $W$ . In particular photo-production of  $\Upsilon$  mesons provides due to the relatively large bottom quark mass an excellent test of perturbative low  $x$  BFKL evolution. While the bottom mass is likely to completely suppress to a very good accuracy non-linear corrections to BFKL evolution, characteristic for the regime of saturated gluon densities, observation of such effects should be in principle possible in  $J/\Psi$  production, where the saturation scale can reach in principle values of the order of the charm mass, see *e.g.* Reference [14]. For such studies the BFKL description provides therefore at the very least an important benchmark in the sense that it tests the possibility to describe the given data set without the inclusion of non-linear high density effects. In the following we present a few aspects of a description of both  $J/\Psi$  and  $\Upsilon$  photo-production data which is based on the (collinear improved) NLO BFKL fit to HERA data of Reference [15, 16]. For the full details of this study we refer the interested reader to Reference [17].

## Results & Outlook

The central results of the study are shown in Figures 1, 2 ( $J/\Psi$ ) and Figures 3, 4 ( $\Upsilon$ ). While the BFKL fits provide a very good description of the energy dependence, BFKL fit 1 requires a relatively large adjustment in the overall normalization (of order 3 – 3.5); for fit 2 the necessary adjustment is of order one. To improve and stabilize the BFKL

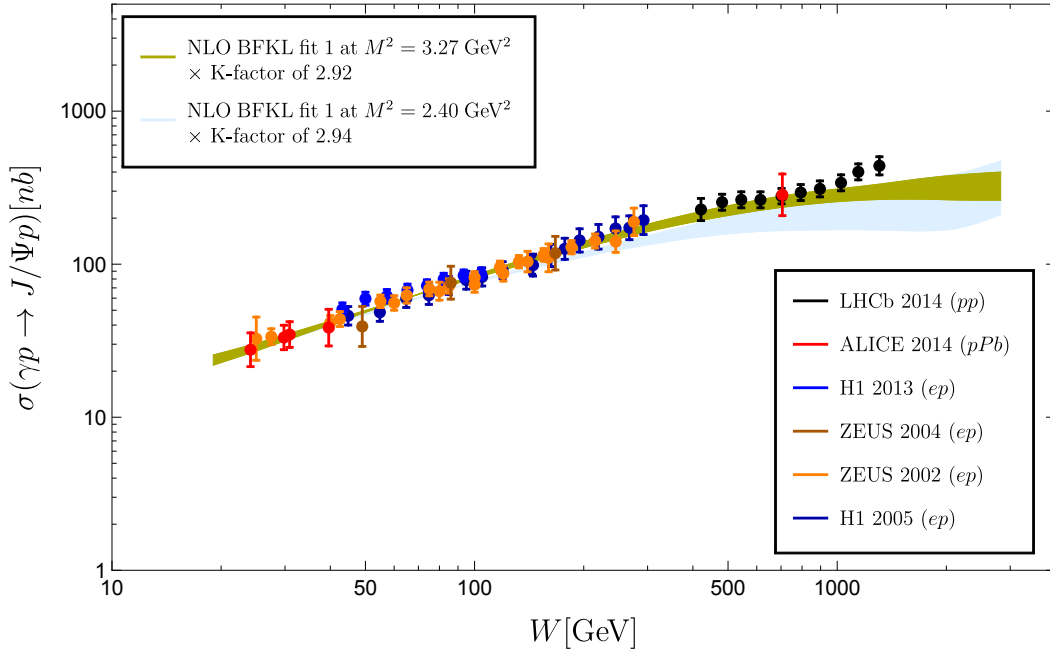
description further it will be necessary to provide a re-fit of HERA data which takes into account heavy quark masses and possibly now available next-to-leading order corrections to the virtual photon impact factor with massless quarks. In addition it might be possible to achieve a more precise description of light seaquarks in the fit, using techniques developed in Reference [18, 19, 20]. For the  $\gamma p \rightarrow V p$  cross-section this would then require the determination of corresponding NLO corrections using for instance the techniques developed and used in NLO calculations within high energy factorization [21, 22, 23].

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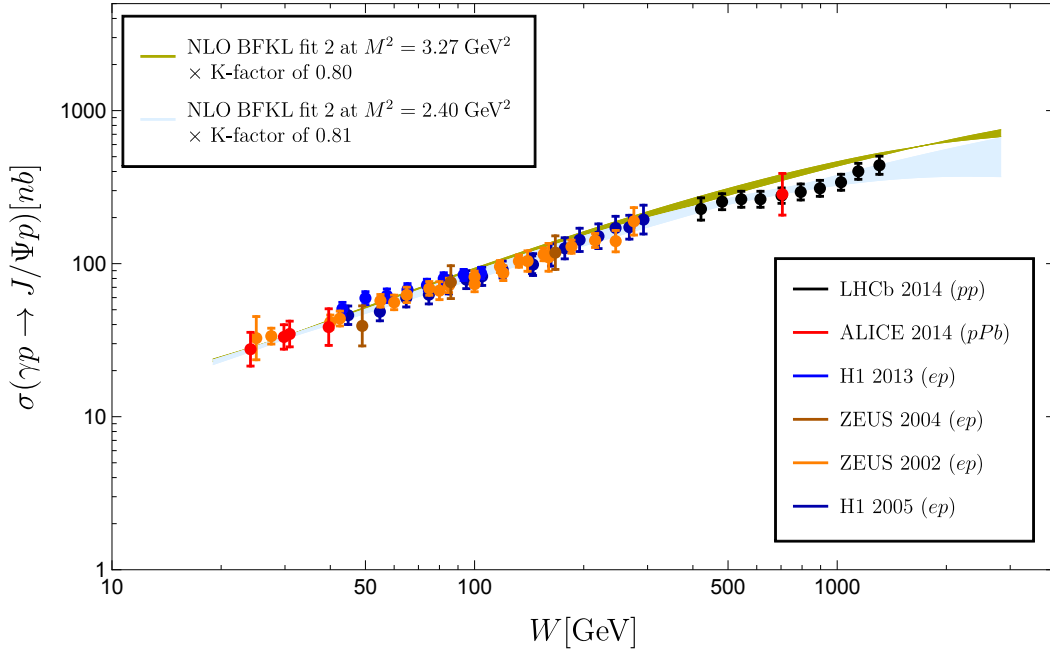
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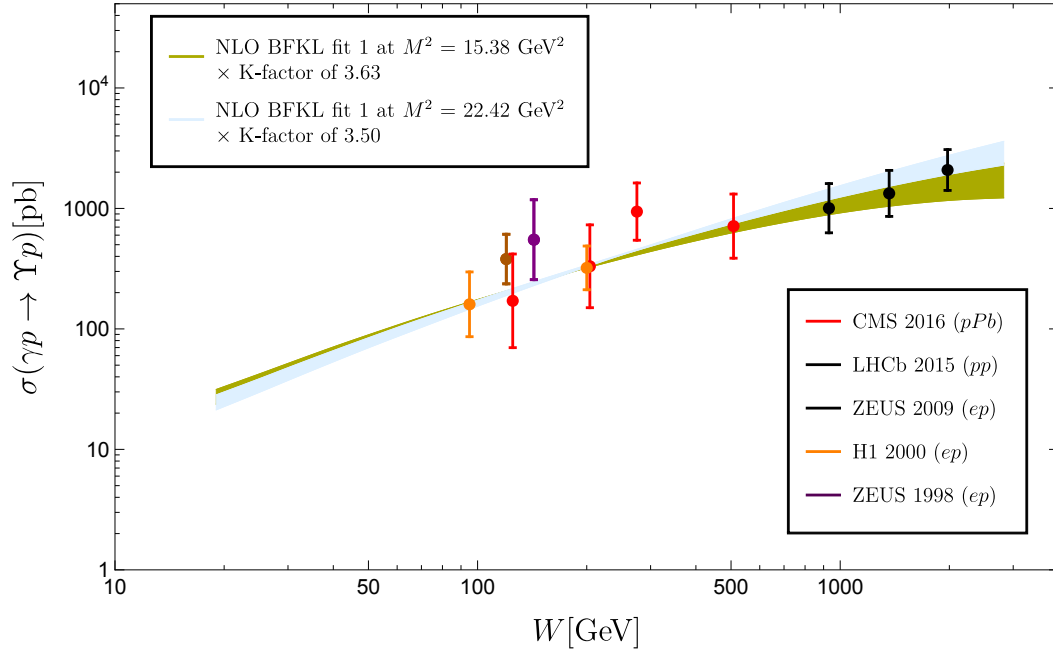
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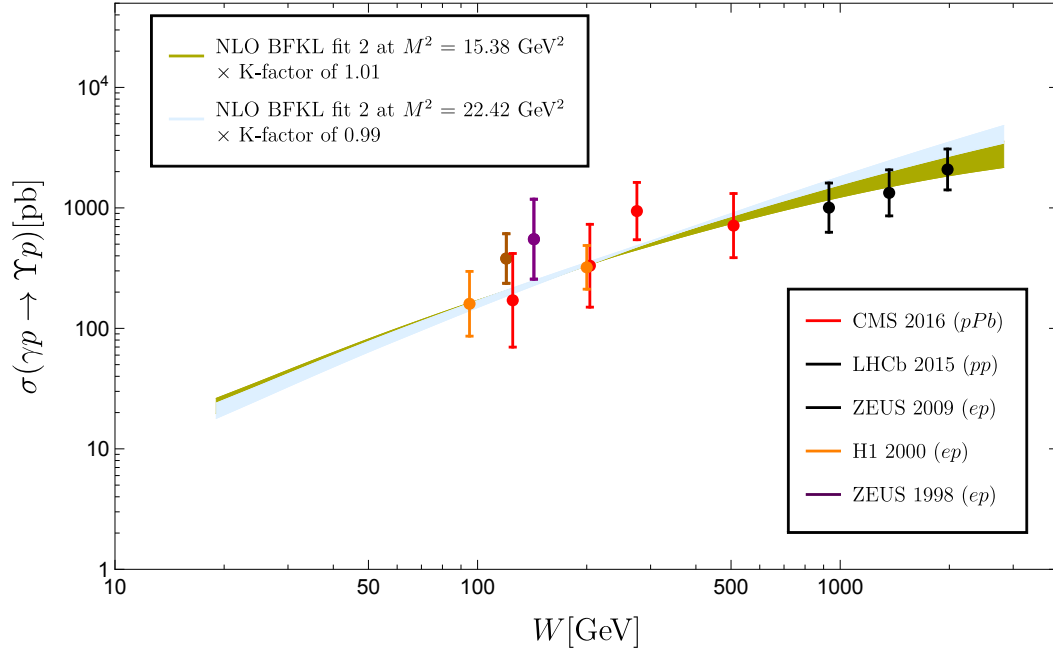
**FIGURE 1.** Energy dependence of the  $J/\Psi$  photo-production cross-section as provided by the BFKL fit 1. The uncertainty band reflects a variation of the scale associated with the running coupling. We also show photo-production data measured at HERA by ZEUS [5, 6] and H1 [7, 8] as well as LHC data obtained from ALICE [1] and LHCb ( $W^+$  solutions) [2].



**FIGURE 2.** Energy dependence of the  $J/\Psi$  photo-production cross-section as provided by the BFKL fit 2. For further details see Figure 1



**FIGURE 3.** Energy dependence of the  $\Upsilon$  photo-production cross-section as provided by the BFKL fit 1. The uncertainty band reflects a variation of the scale of the running coupling. We also show HERA data measured by H1 [9] and ZEUS [10, 11] and LHC data by LHCb [3] and CMS [4].



**FIGURE 4.** Energy dependence of the  $\Upsilon$  photo-production cross-section as provided by the BFKL fit 2. For further details see Figure 3